Additional Factors Affecting the Species

"Pacific Northwest salmon are subject to a world of multiple stresses, including human impacts on streamflows and salmon habitat. Climate change adds another dimension to, and in many cases exacerbates, these stresses."

The Climate Impacts Group at the University of Washington (2004)

In addition to the "H factors" of habitat, harvest and hatcheries, Puget Sound Chinook and Coastal-Puget Sound bull trout are affected by regional and global factors such as climate change and fluctuating ocean conditions. Although it is clear that these factors directly affect salmon and bull trout, scientists are only beginning to unravel the secrets of how these processes impact the food chain, precipitation and snowpack, and other habitat features. Temperature conditions and ocean cycles affect migration and the abundance of predators, and are essential in the production of the minute organisms that provide the food supply for salmon and bull trout to grow and flourish.

At the other end of the food chain, salmon and bull trout are part of the food supply for several species of marine mammals. The population size and feeding habits of these opportunistic predators may also have a substantial effect on salmon and bull trout populations, particularly where human modifications and structures make it easy for them to target specific salmon runs. However, specific information about the extent of predation by marine mammals on particular species or populations of salmon is largely unknown.

These three factors - climate change, ocean conditions, and marine mammal interactions are the focus of considerable research related to their effects on salmon and other species of fish. A lengthy discussion of these factors is not possible in the Puget Sound Chinook recovery plan, thus these factors are described here in terms of a brief description of research findings and sources of additional information. Although the residents of Puget Sound may not have direct influence over climate change, ocean conditions or marine mammal populations, several of the adaptive strategies suggested by the scientific community stress the need to ensure that local habitat conditions are protected and restored as a buffer against the coming changes, and that harvest and hatchery management consider these long term factors in their decision-making.

Climate Change in the Pacific Northwest

Data collected during the 20th century revealed widespread increases in average annual temperature and precipitation, and decreases in the April 1 snow water equivalent. Snow water equivalent is a common measurement for the amount of water contained in snowpack and is an important indicator for forecasting summer water supplies. 1990-2000 was the warmest decade on record, and was warmer than any other decade by 0.9°F (CIG, 2004).

Long term models for climate change in the 21st century show evidence of trends including, "region-wide warming, increased precipitation, declining snowpack, earlier spring runoff, and declining trends in summer

Indicator	Observed 20th century changes	Projected mid 21st century changes
Temperature	Region-wide warming of about 1.5ºF (1920-2000)	• 2020s: average increase of 2.7ºF • 2040s: average increase of 4.1ºF
Precipitation	Region-wide increase in precipitation since 1920	Uncertain, although most models project wetter winters and drier summers.
April 1 snowpack	Substantial declines (>30%) at most monitoring stations below 6,000 feet	Continued decrease in April 1 snowpack in mid and low elevation basins. Projected decrease in April 1 snowpack for the Cascades Mountains in Washington and Oregon relative to 20th century climate: • -44% by the decade of the 2020s (based on +3ºF avg. temp change) • -58% by the decade of the 2040s (based on +4.5ºF avg temp change)
Timing of peak spring runoff	Advanced 10-30 days earlier into the spring season during the last 50 years, with greatest trends in the PNW	Earlier peak spring runoff expected on the order of 4-6 weeks
Summer streamflow	Declining in sensitive PNW basins. Example: May-Sept inflows into Chester Morse Lake in the Cedar River watershed (WA) as a fraction of annual flows have decreased 34% since 1946.	Continued and more wide-spread declines. Example: April-Sept natural streamflow in the Cedar River (WA) projected to decrease 35% by the 2040s (based on a 2.5ºF increase in average temperature.

Figure 3.33 Observed and Projected Impacts of Climate Change in Major Climate/Hydrologic Indicators (Sources: Mote et al. 1999; Miles et al. 2000; Mote 2003; Snover et al. 2003; Steward et al. 2004; Wiley 2004 as cited in CIG, 2004)

streamflow." (CIG, 2004) Most of the models predict warmer, wetter winters and warmer, drier summers for the Pacific Northwest. Figure 3.33 contains a summary of the observed and projected impacts of climate change relevant to salmon and bull trout populations.

Salmon and bull trout have lived in the Pacific Northwest for millions of years. As different species and populations of salmon have developed over time, they have acquired specific behaviors for their migration, rearing and spawning life cycles that are attuned to temperature and streamflow. This complex life cycle makes it difficult to predict how they will react to climate changes, and their response will also vary depending on the habitat conditions in a particular river system and estuary. Changes in temperatures away from optimal conditions can influence salmon and bull trout in each of their life stages. Even a small increase in temperature can change migration timing, reduce growth, reduce the supply of available oxygen in the water, and increase the susceptibility of fish to toxins, parasites and disease. The increase in stream temperatures can also contribute to a reduction in the preferred species of insects that are used for food (NWF, 2005). Earlier spring runoff and lower summer flows may make it difficult for returning adult salmon to negotiate obstacles. Excessively high levels of winter flooding can scour eggs from their nests in the streambeds and increase mortalities among overwintering juvenile salmon and bull trout.

Adaptive strategies to cope with the projected changes largely focus on the need to maintain salmon and bull trout populations through conservation and restoration of freshwater and estuarine habitat. Additionally, it has been recommended that harvest and hatchery managers pay particular attention to the time lag associated with impacts of natural variability in one season on the viability of populations in successive seasons. For example, productivity may decline following drought conditions and should be factored into hatchery production targets and harvest regimes; similar issues are already being considered during technical planning forums for harvest.

The predicted increased winter flooding, decreased summer and fall streamflows, and elevated warm season temperatures in the streams and estuaries are likely to further degrade conditions for salmon that are already stressed from habitat degradation. Although the impacts of global climate change are less clear in the ocean environment, early modeling efforts suggest that, "warmer temperatures are likely to increase ocean stratification, which in the past has coincided with relatively poor ocean habitat for most Pacific Northwest salmon, herring, anchovies, and smelt populations." (CIG, 2004)

Ocean Conditions

Ocean conditions influence Chinook population abundance, distribution and survival in the marine environment. A number of studies have indicated that salmon survival during the first few months at sea is linked to ocean conditions such as sea surface temperature and salinity. This critical period of climatic influence on their survival occurs largely in coastal and estuarine environments. (Francis and Mantua, 1996; NMFS, 1998) Large-scale weather patterns affect food supplies, predator distribution and abundance, and migratory patterns for Chinook salmon. Climatic conditions can change the prevailing currents and the associated ocean productivity from nutrient-rich cold waters. The shifting currents, named either "El Nino" or "La Nina," can produce widely varied cycles of productivity. (NMFS, 1998)

Scientists utilize several indices to look at the changes in ocean conditions, particularly with respect to temperatures and wind patterns. The Pacific Decadal Oscillation (PDO) and the El Nino/ Southern Oscillation (ENSO) are cycles that appear to have significant influence on salmon survival and migratory patterns. During El Nino and/or warm phase PDO cycles, higher Pacific Ocean temperatures and changes in wind patterns may reduce the upwelling of nutrients from the ocean floor, thereby affecting the entire food web in the Pacific. Wind-driven mixing replenishes nutrients to rich surface waters where phytoplankton occur, thereby promoting biological productivity at the base of the food chain and working its way up to salmon and other species of fish (NWF, 2005).

Comparisons of climate patterns with the levels of fisheries harvest in the northeast Pacific appear to show a relationship between these large scale changes and several salmon populations (Francis and Mantua, 1996; NMFS, 1998). As scientific understanding of these processes has improved, fisheries managers have started to utilize information on favorable or unfavorable ocean conditions in their harvest planning forums (NWF, 2005).

"Anadromous salmonids have managed to persist in the face of numerous climatic events and changes. The long term persistence of Chinook salmon populations depends on their ability to withstand fluctuations in environmental conditions. It is apparent that the combination of tremendous freshwater habitat loss, and extremely small anadromous salmonid populations has caused these fish to be more vulnerable to extirpation arising from natural events. Until salmonid populations reached their recent critical levels, these environmental conditions largely went unnoticed. Therefore, it would seem that environmental events and their impacts on remaining salmonid populations may become a more significant factor for decline as unstable Chinook salmon populations reach particularly low levels." (NMFS, 1998)

Marine Mammal Interactions

Several species of marine mammals prey on salmonid populations in the Pacific Northwest including California sea lions (Zalophus californianus), Pacific harbor seals (Phoca vitulina) and killer whales (Orcinus orca). Due to the depressed status of many salmon populations, the presence of marine mammals concurrent with salmon migration has been identified as a concern, but the limitations in available data make it difficult to determine the extent of impact.

California Sea Lions and Pacific Harbor Seals

In the 1994 Amendments to the Marine Mammal Protection Act, Congress directed that a scientific study be conducted to determine whether California sea lions and Pacific harbor seals are having an impact on threatened and endangered populations of salmon on the West Coast of the United States. A working group was formed by NMFS and submitted a report to Congress in 1997, entitled, "Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon and California."

The report indicated that sea lion and harbor seal populations are increasing and interactions with West Coast fisheries are on the rise. The working group could not determine if these species were having a significant negative impact on any specific wild salmonid population, with the exception of documented impacts to the winter steelhead population that migrates through the Ballard Locks in Seattle. The study identified the geographic areas of greatest concern in each state, along with the elements of a research program to assess impacts (NMFS, 1997).

The population of California sea lions has been increasing at an annual rate of about 5% per year since the mid-1970s and their numbers were estimated to be more than 161,000 off of Washington, Oregon and California in 1994. Although they breed and pup in southern California, male sea lions migrate northerly along the West Coast from September to May, coinciding with the migration of several depressed runs of salmon. Pacific harbor seals in the three states have been increasing at a rate of about 5-7% annually since the mid-1970s and the population in Washington State was estimated to be 34,134 in 1993-1995.

Harbor seals are present year round in western Washington, and California sea lions are present in the fall, winter and spring. The geographic areas of concern for interaction between California sea lions and Pacific harbor seals with threatened salmonid populations identified by the NMFS Working Group included the following:

- **Strait of Juan de Fuca/San Juan Island:** The Working Group expressed concern for predation on juvenile and adult Chinook salmon and summer chum salmon in this area, particularly in Discovery and Sequim Bays.
- **Hood Canal:** The Working Group indicated that juvenile migration patterns in this region make them less vulnerable to predation. However, predation on adult salmon, particularly summer chum, was flagged as a concern.
- **Northeastern Puget Sound Bays (Bellingham Bay, Skagit Bay):** Harbor seals are present year round and juvenile salmon are vulnerable to predation during outmigration. During April-to-June, both juvenile and adult salmon from threatened populations are present and subject to predation. California sea lions are not considered to be a threat due to their low abundance in these areas.
- **Puget Sound:** Harbor seals are present year-round and California sea lions are present in the fall, winter and spring. Both species have been observed upriver for several miles in many rivers draining into Puget Sound. "More than 1,000 California sea lions, which occur seasonally near the mouth of the Snohomish River, have been observed 8-10 miles upriver and prey on free-swimming salmonids in the estuary. As many as 300 harbor seals haul-out on log booms near the mouth of the Snohomish River in fall and winter and have been reported 15-20 miles upriver....In the Nisqually, both seals and sea lions are common at the mouth; sea lions have been observed preying on free-swimming salmonids and have been observed as far as 40 miles upriver." (NMFS, 1997) The Working Group also reported observed predation in the Green River, Ballard Locks, Lake Washington and the White River. Overall concern was expressed for predation on adult and juvenile Chinook and other salmonid species.

Despite these observations, the Working Group noted that not all of the observed marine mammals near an active salmon run are actively feeding on salmonids. Several studies in the U.S. and Canada indicate that most predation was attributable to a small percentage of the observed population of marine mammals, suggesting that removal would not be an effective solution in many areas. The Working Group described several measures of harassment to deter marine mammals from fish predation and fishing gear.

The complexity of ecosystem level impacts and the limited amount of information has made it difficult to accurately estimate the amount of biomass consumed by California sea lions and harbor seals. Overall, the Working Group estimated total consumption of about 217,400 metric tons by sea lions and seals in Washington, Oregon and California and found that it was almost half of what had been cumulatively harvested in multi-species commercial fisheries. Estimates of the proportion of that consumption on individual species could not be made. Limited studies in Everett, WA demonstrated that the most frequent prey were Pacific whiting and Pacific herring. Based on scat samples, salmonid remains were found in 2% of the harbor seal samples and 15% of those of the sea lions.

Killer Whales

NMFS has prepared a preliminary draft Conservation Plan for Southern Resident Killer Whales (NMFS, 2005) describing characteristics of the three pods that reside for part of the year in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca and Puget Sound, primarily during the spring summer and fall. In the description of the diet and forage behavior of the whales, NMFS has indicated that killer whales forage on a variety of marine species ranging from squid, sea turtles, marine mammals, penguins and other seabirds, to several species of fish including herring, tuna, rays, sharks, bottom fish and salmon. Fish are the major dietary component of resident killer whales in the northeastern Pacific. Most of the information about killer whale consumption comes from the analysis of stomach contents from whales that were stranded or those killed during commercial whaling operations. A few studies utilizing direct observations of feeding behavior have added new data in recent years. Preliminary data, primarily from a single study in British Columbia with several data limitations, indicated that salmon were found to represent 96% of the prey during the spring, summer and fall.

"Chinook salmon were selected over other species, comprising 65% of the salmonids taken. This preference occurred despite the much lower numerical abundance of Chinook in the study area in comparison to other salmonids, and is probably related to the species' large size, high fat and energy content, ... and year-round occurrence in the area." (NMFS, 2005)

Based on estimates of food requirements and average size values for combined species of salmon, it is thought that adult killer whales may consume about 28-34 adult salmon daily and that younger whales (<13 years of age) need 15-17 salmon daily to maintain their energy requirements. Although these numbers cumulatively add up to substantial quantities, the impact of killer whale consumption to any particular species is generally unknown, let alone the impact to specific populations of Chinook in Puget Sound.

The relationship of salmon to large-scale factors in the larger ecosystem is the subject for further study, and points to the need to retain viable populations that fulfill existing and future ecosystem functions.

"Long ago my wife and I made a personal commitment to accept salmon as a teacher. It's taken us to a lot of places... Salmon can teach us where in the world we belong and what our responsibilities are."

Tom Jay, Chimacum Creek volunteer and artist

References

Section 1: Habitat Factors

Federal Register 62; May 6, 1997. Endangered and Threatened Species; Threatened Status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon.

Federal Register 63; March 9, 1998. Proposed Rule on the Threatened Status for the Puget Sound Chinook ESU.

Forest Ecosystem Management and Assessment Team, 1993. Forest Ecosystem Management: An Ecological, Economic and Social Assessment. USDA Forest Service.

Governor's Salmon Recovery Office, 2004. 2004 State of Salmon in Watersheds Report. Olympia, WA.

Beamer, E., C. Greene, A. McBride, C. Rice and K. Larsen. 2004. Recovery Planning for Ocean Type Chinook Salmon in the Skagit River: Results of a Decade of Field Studies. Skagit System Cooperative. La Conner, WA. http://www.skagitcoop.org/EB_SkagitChinookStudy-10yearSummary.pdf

Beechie, T.J., E.A. Steel, P. Roni, and E. Quimby (editors). 2003. Ecosystem recovery planning for listed salmon: an integrated assessment approach for salmon habitat. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-58, 183 p.

Greene, C., T. Beechie and E. Beamer, 2003. Linking Habitat-related and Density-dependent Population Responses in Chinook Salmon. Proceedings of the 2003 Georgia Basin/Puget Sound Research Conference. http://www.psat.wa.gov/Publications/03_proceedings/PAPERS/ORAL/5c_green.pdf

Lambert, D., 2001. Washington: A State of Contrasts. Directed Media, Inc. East Wenatchee, WA.

Lichatowich, J.A., 1999. Salmon Without Rivers: A History of the Pacific Salmon Crisis. Island Press. Washington, D.C.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

National Marine Fisheries Service, 1996. Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead. NMFS Protected Species Branch; Portland, OR

National Marine Fisheries Service, 1998. Factors Contributing to the Decline of West Coast Chinook salmon: An Addendum to the 1996 West Coast Steelhead Factors for Decline Report. NMFS Protected Species Branch; Portland, OR

National Marine Fisheries Service; West Coast Chinook Salmon Biological Review Team, 2003. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. Available from the NMFS Northwest Fisheries Science Center; Seattle, WA.

National Marine Fisheries Service; West Coast Chum Biological Review Team,1997. Status Review of Chum Salmon from Washington, Oregon, and California. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWFSC-32.

National Research Council, 1996. Upstream: Salmon and Society in the Pacific Northwest.

Northwest Indian Fisheries Commission, 2004. State of Our Watersheds Report: WRIAs 1-23 (Salmon and Steelhead Habitat Inventory and Assessment Program). www.nwifc.org

Puget Sound Action Team, 2004. State of the Sound 2004. Olympia, WA.

Scholtz, N. 2003. Personal communication with staff at NMFS, Northwest Fisheries Science Center.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp. Corvallis, OR.

State of Washington Governor's Salmon Recovery Office, 2004. 2004 State of Salmon in Watersheds Report. Olympia, WA.

U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife, 2001. Draft Feasibility Cost Sharing Agreement Appendix A - Project Management Plan, Puget Sound Nearshore Ecosystem Restoration Study.

U.S. Fish and Wildlife Service, 2004. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout (Salvelinus confluentus). Available from U.S. Fish and Wildlife Service Region 1; Portland, OR.

Washington Department of Ecology, 2004. Washington State's Water Quality Assessment Report [303(d) & 305(b)]. http://www.ecy.wa.gov/programs/wq/303d/ 2002/2004_documents/wq_assessment_cats2004.html

Washington State Conservation Commission, 1998 - 2004 (depending on WRIA). Salmon and Steelhead Limiting Factors; reports for each Water Resource Inventory Area in Washington State. Olympia, WA. http://salmon.scc.wa.gov/

Washington State Governor's Joint Natural Resources Cabinet, 1999. Statewide Strategy to Recover Salmon: Extinction is not an option. www.governor.wa.gov/gsro/strategy/longversion.htm

Section 2: Harvest

Cohen, F.G., 1986. Treaties on Trial: The Continuing Controversy over Northwest Indian Fishing Rights. A Report Prepared for the American Friends Service Committee. University of Washington Press. Seattle, WA.

Federal Register/ Vol. 63, No. 46/ Tuesday, March 10, 1998. Endangered and Threatened Species: Proposed Threatened Status and Designated Critical Habitat for Hood Canal Summer-Run Chum Salmon and Columbia River Chum Salmon; Proposed Rule

Madson, P.K. and Koss, W.,1988. Washington Salmon: Understanding Allocation. Washington State House of Representatives, Office of Program Research. Olympia, WA.

National Marine Fisheries Service,1997. Investigation of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWFSC-28, 172 p.

National Marine Fisheries Service; West Coast Chum Biological Review Team,1997. Status Review of Chum Salmon from Washington, Oregon, and California. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWFSC-32.

National Marine Fisheries Service, West Coast Biological Review Team; 2003. Preliminary Conclusions Regarding the Updated Status of Listed ESUs of West Coast Salmon and Steelhead.

National Marine Fisheries Service, 2004. Puget Sound Chinook Harvest Resource Management Plan Draft Environmental Impact Statement. USDA/NOAA, Northwest Office. Seattle, WA.

National Research Council, 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press. Washington, D.C.

Pacific Fishery Management Council (PFMC). 2005. Review of 2004 Ocean Salmon Fisheries. Pacific Fishery Management Council. Portland, OR

Pacific Salmon Commission, 2004. Joint Chinook Technical Committee 2003 Report: Catch and Escapement of Chinook salmon under Pacific Salmon Commission Jurisdiction. (available at http://www.psc.org/pubs/TCCHINOOK02-3.pdf)

Puget Sound Indian Tribes and the Washington Department of Fish and Wildlife, 2004. Comprehensive Resource Management Plan for Puget Sound Chinook: Harvest Management Component.

Puget Sound Indian Tribes and the Washington Department of Fisheries, 1985. Puget Sound Salmon Management Plan. Filed with U.S. District Court, Western Washington, October 17, 1985 in relation to U.S. v. Washington, F. Supp. 1606:1405

U.S. Fish and Wildlife Service; May, 2004. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout. USFWS Region 1; Portland, OR.

Washington Department of Fish and Wildlife, 2005. Fish ticket data and personal communication courtesy of T. Scott.

Washington Department of Fish and Wildlife and the Point No Point Treaty Tribes, 2000. Summer Chum Salmon Conservation Initiative.

Section 3: Effect of Hatcheries

Alaska Department of Fish and Game, 2005. Coded Wire Tag Fact Sheet. http://tagotoweb.adfg.state.ak.us/CWT/

Busack, C. A., and K. P. Currens. 1995. Genetic Risks and Hazards in Hatchery Operations: Fundamental Concepts and Issues. Pages 71-80 in H. L. J. Schramm, and R. G. Piper, editors. Uses and effects of cultured fish in aquatic ecosystems, volume 15. American Fisheries Society, Bethesda, MD.

Federal Register; June 3, 2004. Endangered and Threatened Species: Proposed Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead. 69 FR 31354-31359.

Hatchery Scientific Review Group (HSRG)-Lars Mobrand (chair), John Barr, Lee Blankenship, Don Campton, Trevor Evelyn, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Seidel, Lisa Seeb and Bill Smoker. April 2004. Hatchery Reform: Principles and Recommendations of the HSRG. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA 98101 (available from www.hatcheryreform.org).

Lichatowich, J.A., 1999. Salmon Without Rivers: A History of the Pacific Salmon Crisis. Island Press.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

National Marine Fisheries Service Chum Biological Review Team, 2003. Preliminary Conclusions Regarding the Updated Status of Listed ESUs of West Coast Salmon and Steelhead. NMFS Northwest Fisheries Science Center; Seattle, WA.

National Research Council, 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press. Washington, D.C.

Northwest Indian Fisheries Commission and Washington Department of Fish and Wildlife, 1998. Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State. www.nwifc.gov/pdf_public/Disease_Policy_1998.pdf

Washington Department of Fish and Wildlife, 1997. Policy of WDFW and Western Washington Treaty Tribes Concerning Wild Salmon. www.wdfw.wa.gov/fish/wsp/joint/final/fwsptoc.htm

Washington Department of Fish and Wildlife and the Point No Point Treaty Tribes, 2000. Summer Chum Salmon Conservation Initiative.

Washington Department of Fish and Wildlife and the Puget Sound Treaty Tribes, 2004. Puget Sound Chinook Salmon Hatcheries, a component of the Comprehensive Chinook Salmon Resource Management Plan, draft.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Tribes, 1993. 1991 Washington State Salmon and Steelhead Stock Inventory. Washington Department of Fish and Wildlife; Olympia, WA.

Section 4: Additional Factors

Climate Impacts Group (CIG), 2004. Overview of Climate Change Impacts in the U.S. Pacific Northwest. University of Washington. Seattle, WA www.cses.washington/edu/cig. [Numerous additional publication abstracts and sources are available on this website.]

Francis, R.C. and N.J. Mantua, 1996. "Climatic Influence on Salmon Populations in the Northeast Pacific." From McCall, A.D. and T.C. Wainwright, editors; 2003. Assessing Extinction Risk for West Coast Salmon: Proceedings of the Workshop November 13-15, 1996; Seattle, Washington. NOAA Tech. Memo. NMFS-NWFSC-56. (Available from http:www.nwfsc.noaa.gov).

Miles, E.L., A.K. Snover, A.F. Hamlet, B.M. Callahan, and D.L. Fluharty, 2000. "Pacific Northwest Regional Assessment: The Impacts of Climate Variability and Climate Change on the Water Resources of the Columbia River Basin." Journal of the American Water Resources Association 36(2):399-420.

Mote, P.W., D.J. Canning, D.L. Fluharty, R.C. Francis, J.F. Franklin, A.F. Hamlet, M. Hershman, M. Holmberg, K.N. Ideker, W.S. Keeton, D.P. Lettenmaier, L.R. Leung, N.J. Mantua, E.L. Miles, B. Noble, H. Parandvash, D. W. Peterson, A.K. Snover, and S.R. Willard, 1999. Impacts of Climate Variability and Change, Pacific Northwest. NOAA Office of Global Programs, and JISAO/SMA Climate Impacts Group, Seattle, WA. 110 p.

Mote, P.W., E.A. Parson, A.F. Hamlet, K.N. Ideker, W.S. Keeton, D.P. Lettenmaier, N.J. Manua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter, and A.K. Snover. 2003. "Preparing for Climate Change: The Water, Salmon, and Forests of the Pacific Northwest." Climatic Change 61:45-88.

National Marine Fisheries Service, 1996. Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead. NMFS Protected Species Branch; Portland, OR

National Marine Fisheries Service, 1997. Investigation of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWFSC-28, 172 p.

National Marine Fisheries Service, 1998. Factors Contributing to the Decline of West Coast Chinook salmon: An Addendum to the 1996 West Coast Steelhead Factors for Decline Report. NMFS Protected Species Branch; Portland, OR

National Marine Fisheries Service, 2005. Preliminary Draft; Conservation Plan for Southern Resident Killer Whales (Orcinus orca). NMFS Protected Resources Division, Seattle, WA. http://www.nwr.noaa.gov/mmammals/whales/ preliminkwconsplan.pdf

National Wildlife Federation, 2005. Fish Out of Water: A Guide to Global Warming and Pacific Northwest Rivers. National Wildlife Federation, Western Natural Resource Center. Seattle, WA

Snover, A.K., A.F. Hamlet, and D.P. Lettenmaier, 2003. "Climate Change Scenarios for Water Planning Studies: Pilot Applications in the Pacific Northwest." Bulletin of the American Meteorological Society 84(11):1513-1518.

Steward, I.T., D.R. Cayan, and M.D. Dettinger, 2004. "Changes in Snowmelt Runoff Timing in Western North America under a 'Business as Usual' Climate Change Scenario. Climatic Change 62:217-232.

Wiley, M.W., 2004. Analysis Techniques to Incorporate Climate Change Information into Seattle's Long Range Water Supply Planning. Master's Thesis, Department of Civil and Environmental Engineering, University of Washington; Seattle, WA